## Conscious and unconscious vision

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**Publication date**
2009

# Chapter 6.

# Discussion

## Summary

The experiments laid out in this thesis show that object detection (chapter 2, 3 and 4) and categorization (chapter 5) can occur outside of consciousness in the FFS. Conscious vision on the other hand goes hand in hand with successful figure-ground segregation and is selectively associated with RP (all chapters), reaching back all the way to area V1 (chapter 4 and 5). Together, these data challenge the notion that figure-ground segregation is a prerequisite for object detection and object categorization (Marr, 1982; Nakayama, et al., 1995; Rubin, 1958, see Figure 6.1a), but rather that object detection and categorization are a starting point for figure-ground segregation. In this view the FFS initially causes objects to be detected and categorized in high visual areas, subsequently triggering the recurrent processes that are necessary for figure-ground segregation and conscious vision to occur (see Figure 6.1b).

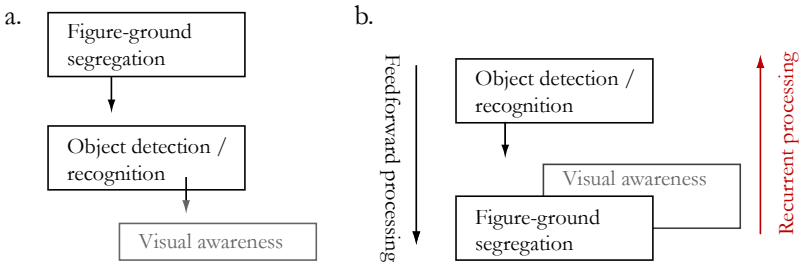


**Figure 6.1** *Models of visual information processing specifying the relationship between figure-ground segregation, object detection/categorization and visual awareness.(a) Figure-ground segregation precedes object detection/recognition and visual awareness. (b) Object detection/categorization is realized in the FFS, Figure-ground segregation and visual awareness is enabled through RP. Object detection/categorization therefore precede Figure-ground segregation and visual awareness.*

## The function of consciousness

If object detection and categorization take place prior to the processes effecting consciousness, it becomes questionable whether object detection and categorization can be considered primary functions of consciousness, as many people do on intuitive or definitional grounds (e.g. Dehaene, et al., 2006). This brings up the question what – if anything – consciousness is good for. As shown in this thesis as well as many other studies (e.g. Boehler, et al., 2008; Lamme, Super, et al., 1998; Pascual-Leone & Walsh, 2001; Super, et al., 2001), consciousness is consistently associated with RP. Therefore, a point of departure for answering this question maybe to inquire what RP is good for. As outlined in the introduction of this thesis, a variety of largely mutually non-exclusive proposals have been put forward in the literature, such as figure-ground segregation, binding, perception of detail and ambiguity resolution (Di Lollo, et al., 2000; Hochstein & Ahissar, 2002; Lamme, 1995; Rao & Ballard, 1999; Roelfsema, et al., 1998). Given the co-occurrence of consciousness and RP and the phenomenological nature of consciousness, it becomes appealing to view consciousness as the phenomenological expression of functions supported by RP (see Figure 6.2). From this perspective, rather than talk about the 'function' of consciousness, a more accurate description might be that RP supports certain functions, and that consciousness is the phenomenological expression of these functions.

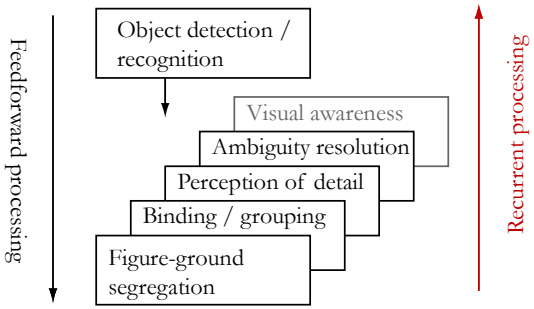


**Figure 6.2** *Visual awareness is the phenomenological expression of functions carried out through RP.*

## The function of RP and how it relates to attention and visual consciousness

Although the proposed functional roles of RP are diverse, a unifying principle behind them seems to be that they enable the integration of visual information across cortical areas. For example, in figure-ground segregation, the role of RP is to use information about the presence and shape of objects in high visual areas to automatically label neurons in low visual areas as either foreground or background (Lamme, 1995; Roelfsema, et al., 2002). A similar role is played out by RP in object based attention by intentionally driving a labeling operation of low level neurons representing object segments by making use of high level neurons representing the objects themselves (Roelfsema, et al., 1998). In perceptual hypothesis testing and reverse hierarchy theory, RP is used to resolve ambiguity by integrating information represented in high visual areas with large receptive fields with information represented in low visual areas with small receptive fields (Di Lollo, et al., 2000; Hochstein & Ahissar, 2002). Despite the fact that informational integration across visual areas is a central theme, aspects of these theories are incompatible, especially in the way they relate RP to attention and visual consciousness.

For example, in Roelfsema's account of object based attention as well as in reverse hierarchy theory, RP enhances spatial resolution through focused attention (Hochstein & Ahissar, 2002; Roelfsema, et al., 1998). This seems to suggest that RP and attention are closely related, or may even lead some to conclude that RP itself is the neural correlate of attention. Studies of figure-ground segregation (Marcus & Van Essen, 2002; Scholte, et al., 2006) and theories of visual consciousness (Lamme, 2003, 2006) on the other hand assert that RP is automatic (pre-attentive), and occurs independently of focused attention. In fact, a number of arguments favor the hypothesis that RP is *not* the correlate of attention. For example, it has been shown that RP continues to be in effect even when subjects do not attend to a stimulus (Scholte, et al., 2006, but also in chapter 5 of this thesis). Conversely, it has also been shown that fully attended stimuli that are masked do not evoke RP (Fahrenfort, et al., 2007, chapter 2 of this thesis; Lamme, et al., 2002) and even fully attended stimuli in plain view sometimes fail to evoke RP (Super, et al., 2001).

Such arguments are incompatible with the idea that RP is the correlate of attention. However, this does not mean that attentional selection could not operate through RP, for instance by biasing cortical pathways for processing certain objects, locations or features through feedback (e.g. Gandhi, et al., 1999; Martinez, et al., 1999; Roelfsema, et al., 1998; Zhang & Luck, 2009). Alternatively (or additionally), it may be that RP has different functional roles during different feedback iterations, first carrying signals responsible for figure-ground segregation and later on in time carrying signals related to attentional selection (Roelfsema, et al., 2007).

Another divergence of views between some of these theories concerns how they relate to consciousness, in particular the assumed minimal level of RP that is required for a subject to become conscious of a stimulus. In Hochstein and Ahissar's reverse hierarchy theory, "vision at a glance" (in which the gist of a scene is determined), comes about as soon as high cortical levels are activated. It is therefore implicitly assumed in their theory that this form of visual consciousness can be established on the basis of the FFS alone, however sparse its representation may be. If true, this would invalidate the idea that RP is necessary to establish visual consciousness of a stimulus. It contrasts quite sharply with the view laid out by Lamme (2006) and DiLollo & Enns (2000), in which RP is required for visual consciousness to emerge in any way. Although there is evidence that visual selective behavior can be triggered on the basis of the FFS (VanRullen & Koch, 2003) and that the information required to extract the gist of a scene can be processed in the FFS (Thorpe, et al., 1996), there is little evidence that subjects can *explicitly* detect the gist of a scene on the basis of the FFS alone. In fact, much evidence to the contrary exists, showing that mere activation of high level areas is insufficient to reach a conscious state (chapters 2, 4 and 5 of this thesis, but also Kouider, et al., 2008; G. Kovacs, et al., 1995; Marois, et al., 2004; Moutoussis & Zeki, 2002). Nevertheless, it remains an open question what level of RP is necessary for consciousness to emerge or how to determine this. An operational way out may be to *define* consciousness as the phenomenological expression of RP's functions, in which case the degree to which a system experiences consciousness is directly on par with the degree to which RP's functions (e.g. figure-ground segregation, binding,

perception of detail and ambiguity resolution) are successfully carried out. A similar view has been put forward by Lamme (2003, 2006) in which it is proposed to define consciousness as RP.

## Some speculation: consciousness as an epiphenomenon?

When defining consciousness as the phenomenological expression of functions supported by RP, the question remains why (or how) this phenomenological expression occurs. Some may argue that consciousness should be branded as an epiphenomenon: a secondary phenomenon caused by physical phenomena, but without any causal or functional role in these phenomena. This would be true if consciousness were a superfluous property altogether, one that could be taken out without consequence. In thought experiments, philosophers have invoked the notion of a 'zombie', an apparatus that acts like a human but has no phenomenal experience (e.g. in Shear, 1999). Images like these are brought up to investigate the idea that it is logically possible to imagine a world identical to our own, but without consciousness. This then is used as proof that consciousness has a special status separate from the physical world (Chalmers, 1995).

However, leaving aside the philosophical and epistemological problems associated with disproving the existence of zombies, consciousness and RP have been consistently observed together in many neuroscientific experiments, making the zombie scenario far-fetched. In practice it seems, whenever RP and its functions are in effect, their phenomenological counterpart is also expressed, and when RP is taken out, consciousness goes out the door as well. If this experimental evidence is accepted, saying that consciousness is an epiphenomenon of RP becomes a bit like saying that a bellied out sail is an epiphenomenon of a sailboat gaining speed in the wind: although being bellied out itself may not be a driving functional force (the wind is), it is an inextricable expression of the sailing event that cannot be separated from it. And although many people have the ability to imagine a sailing sailboat without a bellied out sail, few will argue that such a thought experiment now requires being bellied out to be separated from the list of events that can be explained in

physical terms, and even fewer will argue that being bellied out has no functional role in sailing.

Although it is beyond the scope of this thesis to prove that consciousness is functionally relevant or how the mental world can be explained in physical terms (Chalmers' 'hard' problem, 1995), on the basis of current empirical data it seems plausible that there is a functional reason for phenomenal experience to be associated with RP. Some may find it hard to imagine how neuroscience with its strong physicalist basis can bring anything to bear on what this role may be, but we should not forget the important advances that have already been made. Importantly, being able to tie consciousness closely to functions requiring the integration of information across (visual) areas, such as figure-ground segregation, binding and ambiguity resolution (rather than to object detection and categorization), gives us a first glimpse. It suggests that phenomenal experience has something to with activating or locking into distributed representations. Although this does not answer the question why these are phenomenal in nature, it hints at the idea that there is something special about RP-induced distributed (non-local) representations that they inevitably express themselves in the brain in ways that we call phenomenal experience. The distributed nature of consciousness may therefore well be the starting point for inquiring how physical events can lead to (seemingly) non-physical phenomena. Although neuroscience has not solved the mystery of consciousness, it has more than any other discipline, started to give us pointers as to where to look.